

Candidate Extragalactic Radio Sources for Differenced VLBI Tracking With Deep Space Probes

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The application of the Δ VLBI or VLBI switching technique for tracking extragalactic radio sources (ERS) and spacecraft which are at 10 deg or less angular separation offers a method for augmenting the current doppler navigation system. From general radio source catalogs, ERS have been selected which have promising spectral features and correlated flux values suitable for Δ VLBI tracking using the antennas in the Deep Space Network. A computer program has been written which reduces this list to those occurring in a specific region of the celestial sphere near the track of a deep spacecraft. Surveying two current missions, Pioneers 10 and 11, and two future missions, Mariner Venus/Mercury and Viking, reveals numerous opportunities for Δ VLBI.

I. Introduction

The technique of very long baseline interferometry (VLBI) has applications that range from the determination of the radio source positions to the measurement of the separation and orientation of the stations comprising the interferometer. Since it is possible to track man-made radio sources, e.g., a deep spacecraft, in the interferometric mode, the VLBI technique is being adapted for use as a new method for deep space navigation. This method (suggested by I. I. Shapiro of MIT) involves VLBI tracking which switches between spacecraft and radio sources when the angular separation between the two is approximately 10 deg or less. This technique, which will be referred to as Δ VLBI tracking, enables one to determine the angular position of the

spacecraft relative to the natural radio source by analyzing the differenced VLBI observables. The purpose of this article is to show the results of an investigation to determine opportunities for Δ VLBI tracking using several deep space missions, some currently in progress (Pioneers 10 and 11) and two to be launched (Mariner Venus/Mercury and Viking).

II. Discussion of VLBI Navigation

If, in terms of small angular separation, a spacecraft were to "flyby" a natural extragalactic radio source (ERS), it is proposed that VLBI switching or Δ VLBI between the two can lead to accurate determination of the position of the spacecraft with respect to the ERS.

This technique offers a new means for spacecraft navigation and in addition assists in reducing the uncertainty in tracking stations locations, which is a limitation to navigation capability.

The Δ VLBI technique enables one to determine the position of the spacecraft any time it passes near an extragalactic radio source. The fact that the spacecraft position can be determined implies that the Δ VLBI system can augment the existing doppler tracking system and improve the overall navigation capability during the mission. Also, this ability to fix the position of the probe in space is similar to the situation where a spacecraft encounters one of the planets in the solar system. Both circumstances lead to the determination of the position of the spacecraft, from which it is then possible to obtain tracking station locations. As will be shown by the study done, there are numerous ERS "encounters" during a mission's Earth-to-target body phase, thereby increasing the number of opportunities from 1 per mission to several per mission when it is possible to determine the spacecraft location with respect to another object.

Implementation of the Δ VLBI method for navigation will require significant amounts of work. First, a catalog of extragalactic radio sources must be established that defines the coordinate system in which the planetary positions will be defined. The ERS are especially attractive for this work since they have essentially zero proper motion and hence should be the best references to date for defining an inertial frame. The entire operation can only succeed when the two reference frames, ERS and planetary, are precisely aligned.

Another important part involves the selection of specific ERS for use in the Δ VLBI measurements. To help with this, a computer program has been written which selects ERS from a catalog compiled by J. G. Williams of the Tracking and Orbit Determination Section of JPL and plots them along with trajectories of various deep space missions. Sources that are within 10 deg of the spacecraft trajectory are candidates for the Δ VLBI measurements. Although the sources maintained by Williams in his

catalog have been specifically selected from more general radio source catalogs on the basis of promising spectral features and correlated flux values, it is not until they are actually analyzed by the interferometer that proof of their suitability is made. The computer program is useful in limiting the selection of ERS to those which are "encountered" by the spacecraft and therefore worthy of detailed study.

III. Results

Figures 1 and 2 show the results of the studies done using Williams' catalog for selecting sources near the the Pioneers 10 and 11, Mariner Venus/Mercury, and Viking trajectories. There are approximately nine sources in Fig. 1 which involve all but the Viking missions. Encompassed are the cruise and encounter phases of Pioneers 10 and 11 and the Venus and first Mercury encounter for MVM'73. It is interesting to note that Pioneer 10 oscillates between several ERS prior to encounter. Pioneer 11 will fly through the same area, but after periods of retrograde motion which take it beyond the limits of this plot, it returns to a portion of the sky near the occurrence of the first Mercury encounter of MVM'73. This is interesting since it shows that spacecraft flying by different bodies of the solar system do sometimes have a common ERS background. The second and successive MVM'73 Mercury encounters are not shown in this report. However, studying these in the same manner reveals numerous additional sources which will be near its flight path.

The Viking spacecraft do not fly against the ERS sources of Fig. 1 during their Earth-Mars transfer periods. However, Viking missions A and B do themselves traverse the same general regions, passing more than a dozen ERS (Fig. 2). Following arrival at Mars these spacecraft will eventually traverse the region shown in Fig. 1 and in doing so will also pass many other ERS. However, for the primary purpose of assisting in the navigation during the cruise phase of all these missions, Figs. 1 and 2 do show sources which are of top priority for immediate study.

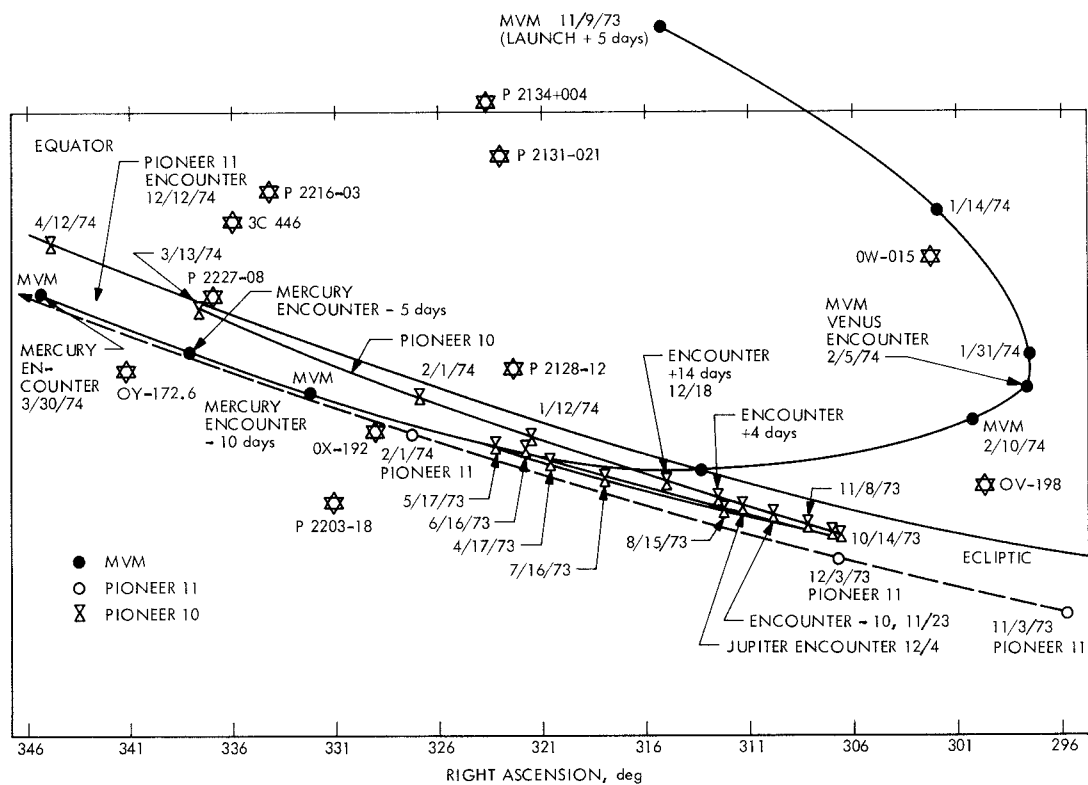


Fig. 1. Pioneers 10 and 11 and Mariner Venus/Mercury Δ VLBI source flybys

